CS 61:
Database Systems

ER models

Agenda

1. Entity Relationship (ER) models
2. Relationships
3. How to build an ER model
4. Reverse and forward engineering

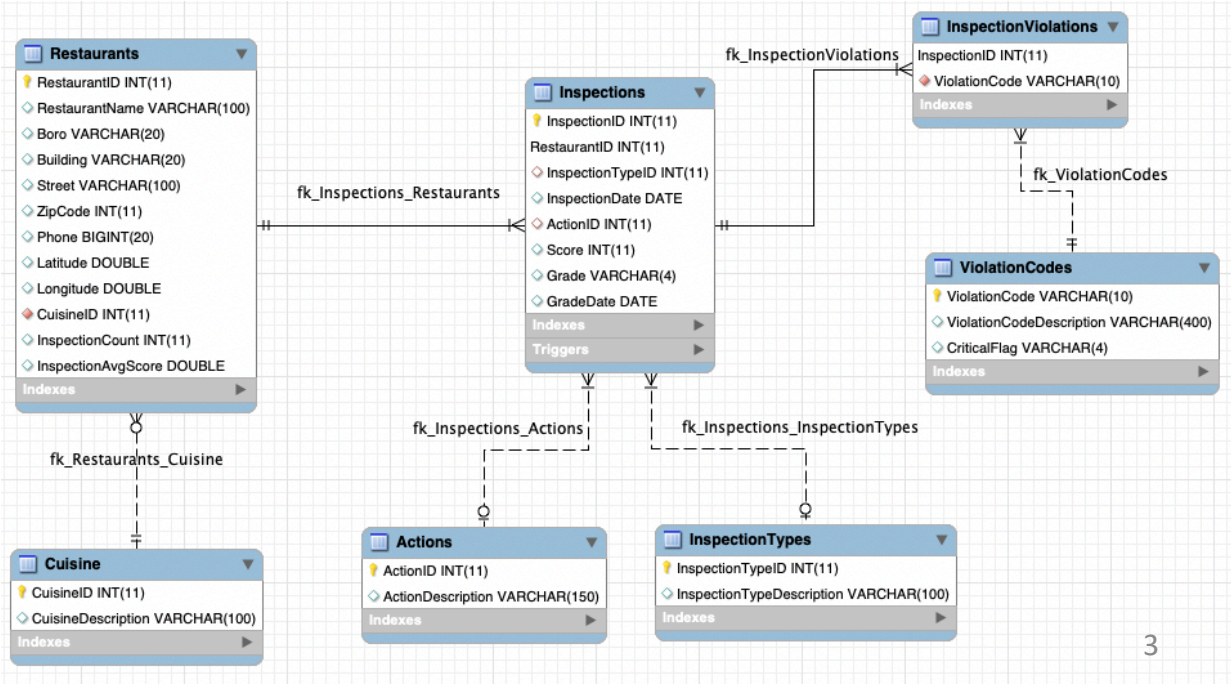
ER models use three basic concepts: Entities, Relationships, and Attributes

Entity Relationship (ER) models

ER model (ERM) rests on three basic concepts:

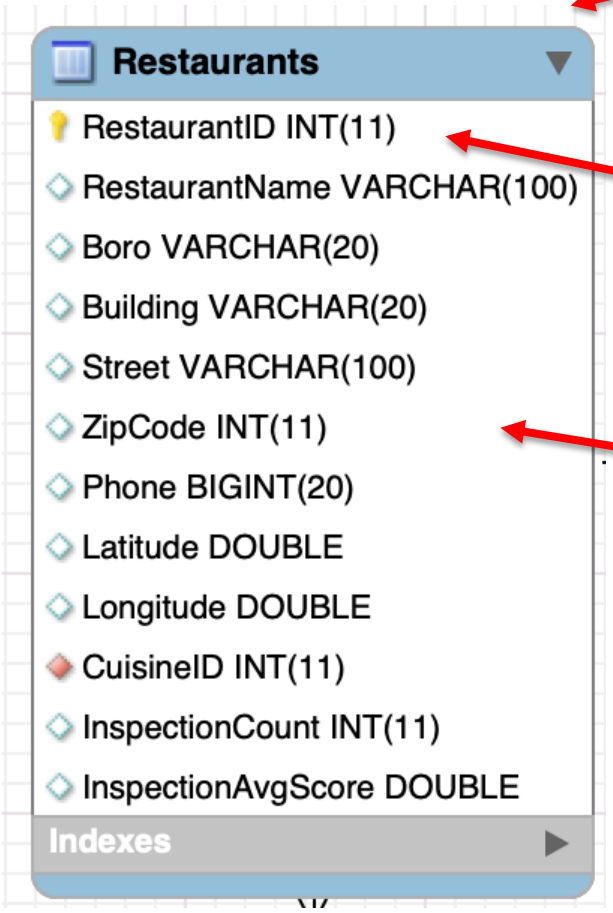
1. Entities: what are the nouns involved?
2. Relationships: how are the entities related
3. Attributes: what characteristics do entities have?

ER diagram (ERD) expresses the overall model graphically



Entities are nouns, each represents people, places, things, concepts, or events

Entity Relationship Diagram (ERD)



Entities are represented as rectangles
Entity set is set of entity instances
Entity set is materialized as a table

Primary key uniquely identifies entity instance
Can be composite key (made up of several attributes)

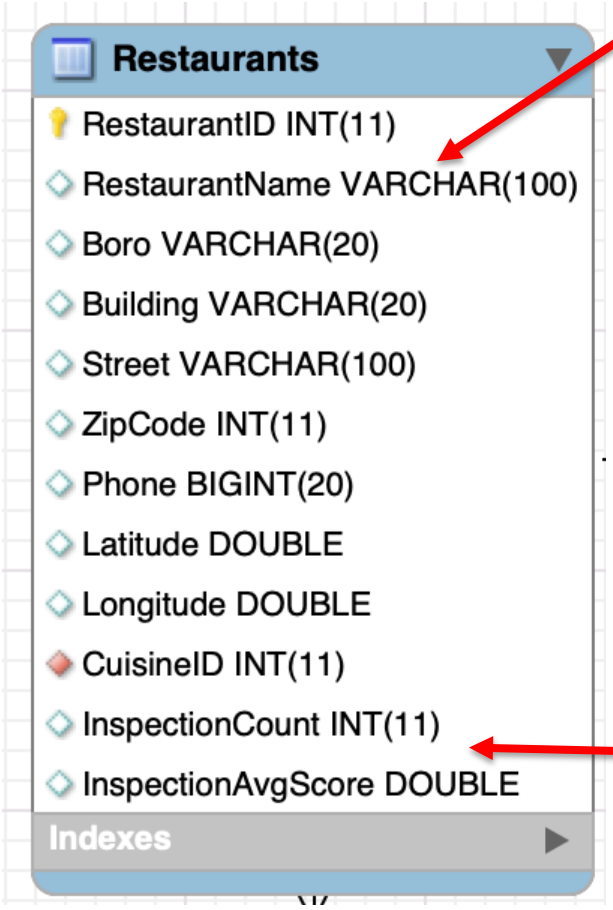
Entities are made up of attributes

Avoid storing same information in multiple tables (avoid data redundancy) unless:

1. **Need speed: joining multiple tables is too slow for business need**
2. **Historical documentation: want to store the state at the time of a transaction (e.g., what was the price of an item when it was sold)**

Attributes describe an entity and have data type

Entity Relationship Diagram (ERD)



Attribute name and data type

MySQL does not support composite attributes

If Name is composite of

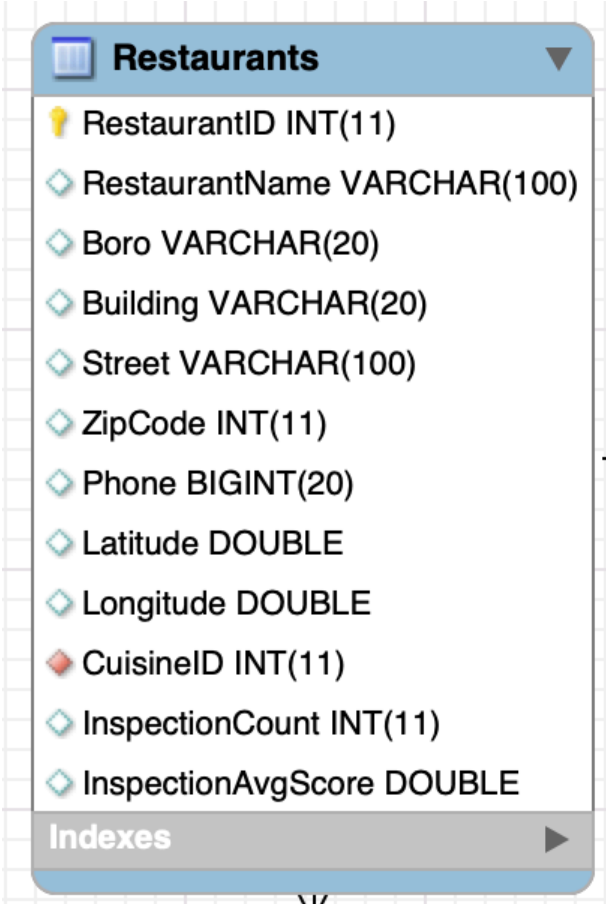
- **First name**
- **Last name**

Just promote all composite components to simple attributes

Some attributes can be derived from other attributes (possibly in other tables)

Value of derived attributes can be stored or computed on demand

Entity Relationship Diagram (ERD)



Derived attribute: store value or compute on demand

	Store computed value	Compute on demand
Advantages	• Fast to access • Can be used to keep track of historical data	• Less space • Computation always yields current value
Disadvantages	• Requires constant maintenance keep value current	• Slow • Adds coding complexity to queries

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2. Relationships
   - One-to-many (1:M)
   - One-to-one (1:1)
   - Many-to-many (M:N)

3. How to build an ER model

4. Reverse and forward engineering

One-to-many relationships are the most common

One-to-many (1:M)

Many side

One side

Notice how links "fan out"

Date: Jan 2, 2018
Score: 7
Grade: A

Date: Feb 4, 2019
Score: 15
Grade: B

Date: Apr 20, 2020
Score: 4
Grade: A

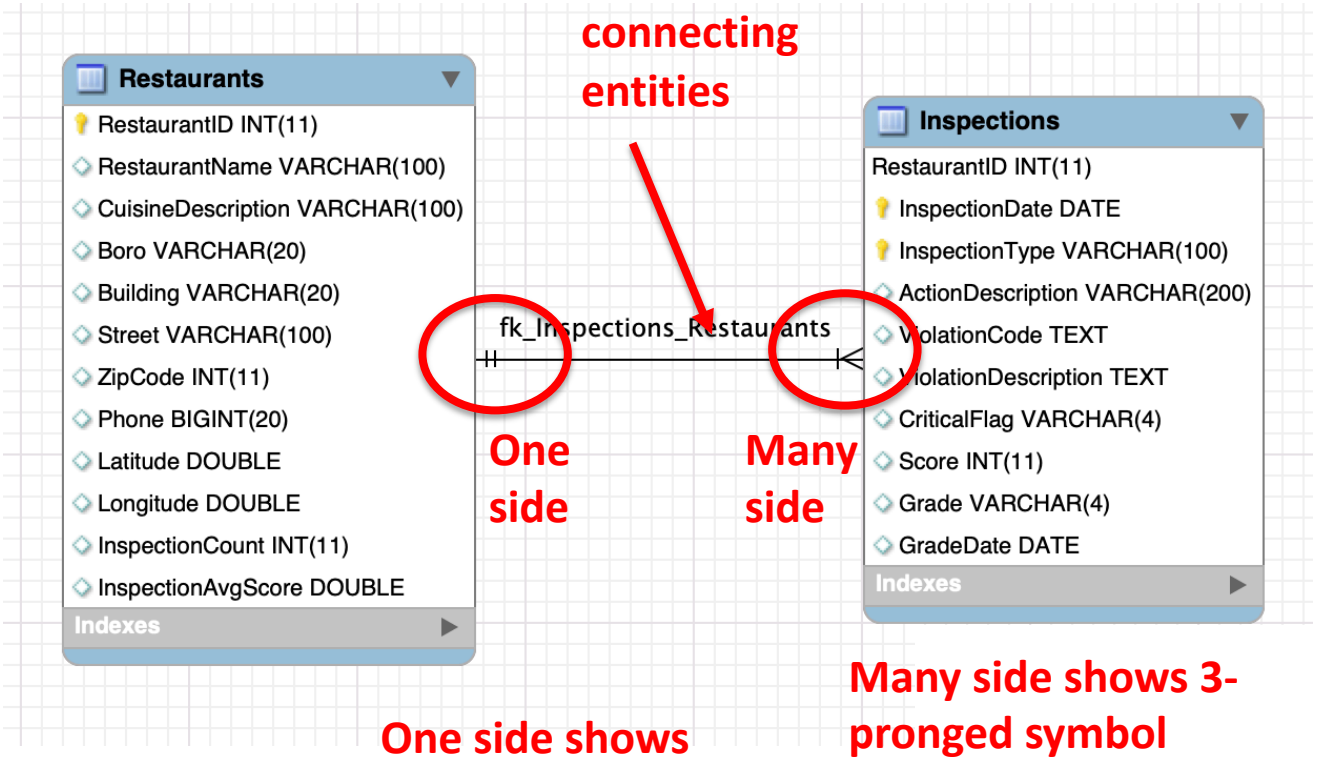
One restaurant can be inspected many times

One inspection is for one restaurant

There is a 1:M relationship between restaurants and inspections

Crow's foot diagram shows one-to-many using a 3-pronged symbol on the many side

1:M relationship on crow's foot diagram



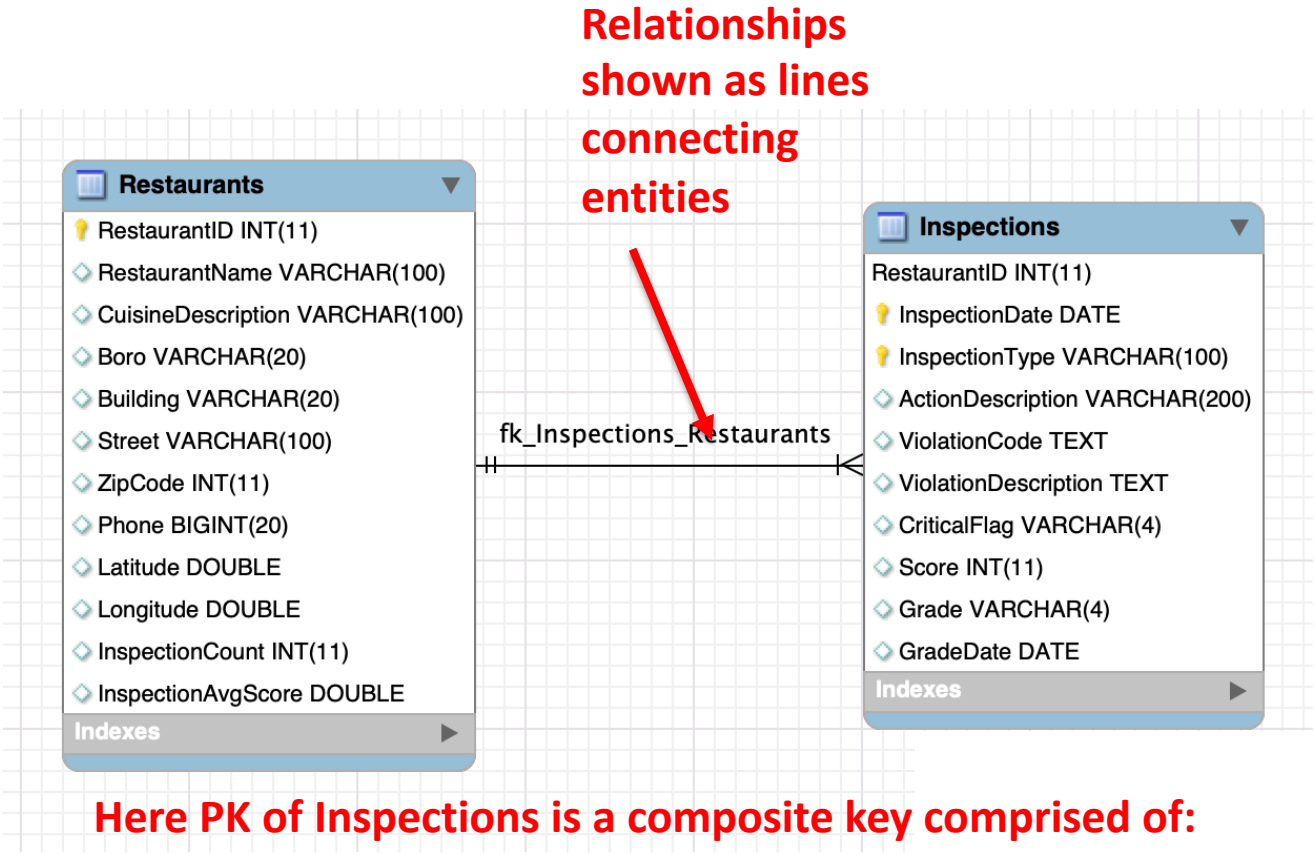
Relationship based on RestaurantID as FK

RestaurantID FK relates an Inspection to a Restaurant

There can be many rows in Inspections that reference the same Restaurant

Solid line indicates a strong (identifying) relationship between entities

1:M relationship on crow's foot diagram



Solid line indicates a strong (identifying) relationship between entities

The related table is existence-dependent on the parent table (cannot exist without the parent)

Related table PK contains part of PK of parent table

Here PK of Inspections is a composite key comprised of: RestauantID, InspectionDate, InspectionType

- **Inspections PK contains part of PK of Restaurants table**
- **Cannot have entry in Inspections without entry in Restaurants**
- **Inspections are existence-dependent on restaurants**

Dashed line indicates a weak (non-identifying) relationship between entities

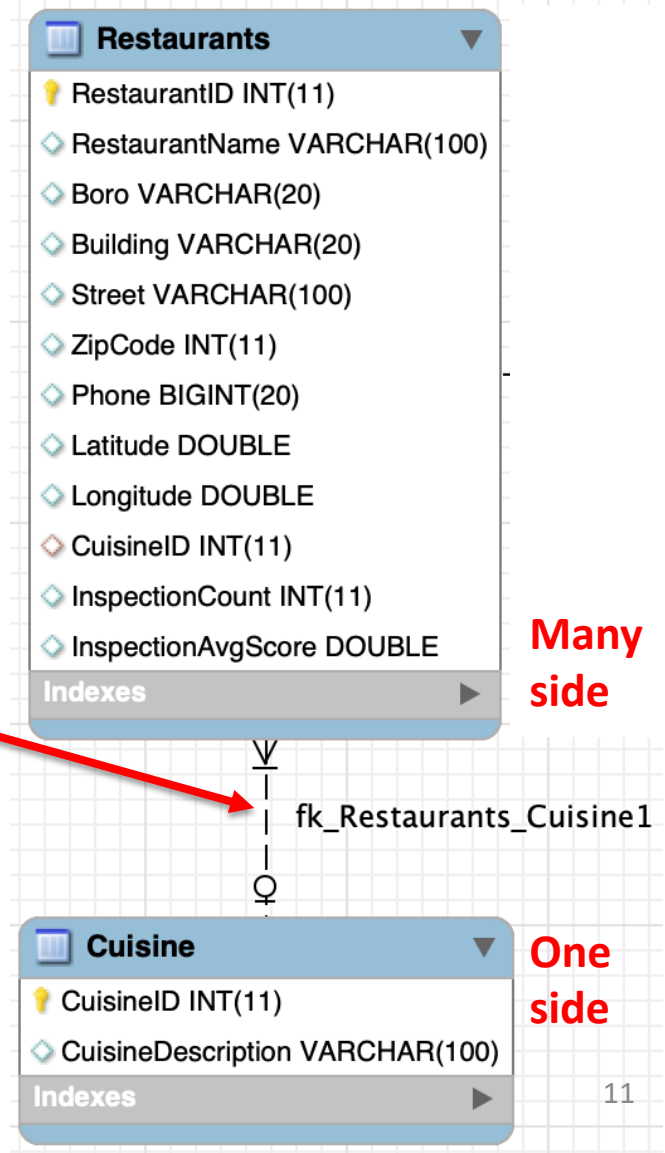
1:M relationship on crow's foot diagram

1 Restaurant can have 1 Cuisine type
1 Cuisine type can have many restaurants

Dashed line indicates a weak (non-identifying) relationship between entities

An entry can be made in a related table even though it is not in the parent table; not existence-dependent

PK of related table does not contain part of PK of parent table

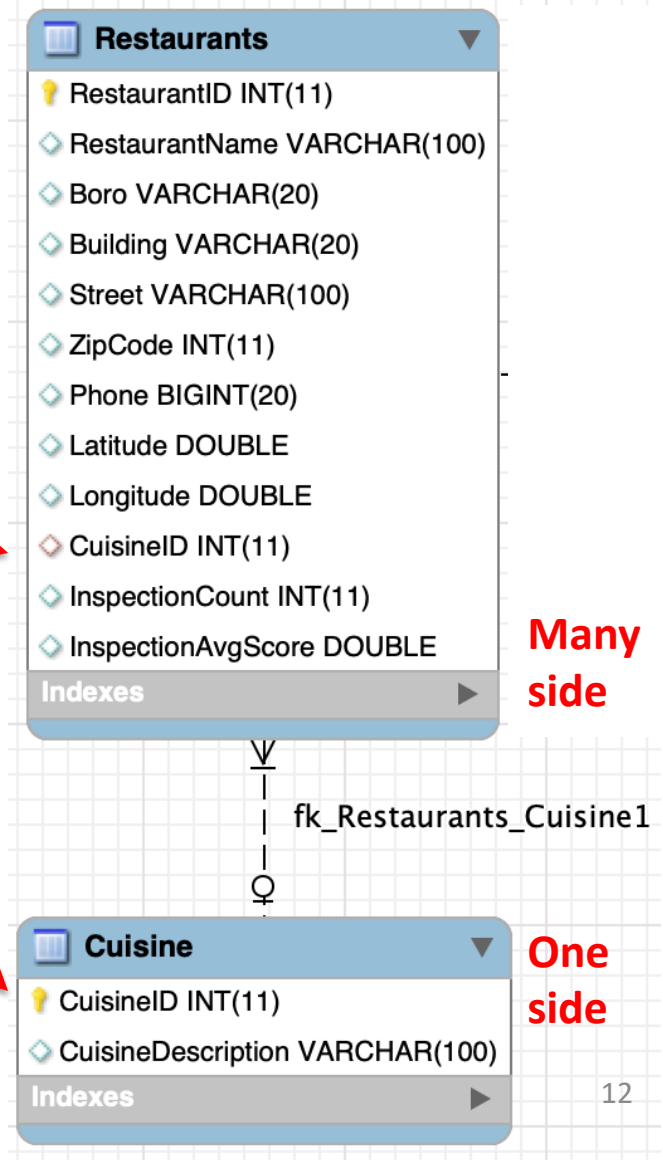


Implement 1:M relationship by including common attribute as foreign key in table

1:M relationship on crow's foot diagram

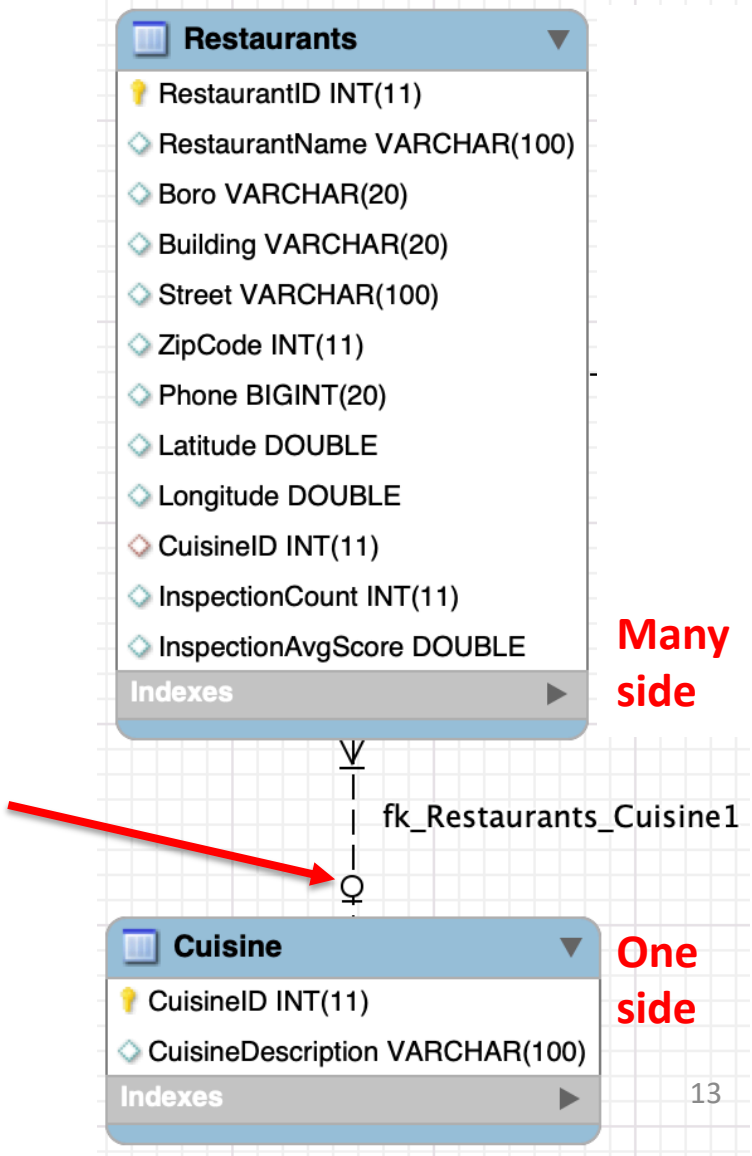
Implement 1:M by using a foreign key on the many side

Foreign key is primary key on the one side



Implement 1:M relationship by including common attribute as foreign key in table

1:M relationship on crow's foot diagram



Circle indicates CuisineID is optional in Restaurants

The "participation" is optional

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One-to-one relationships are somewhat uncommon

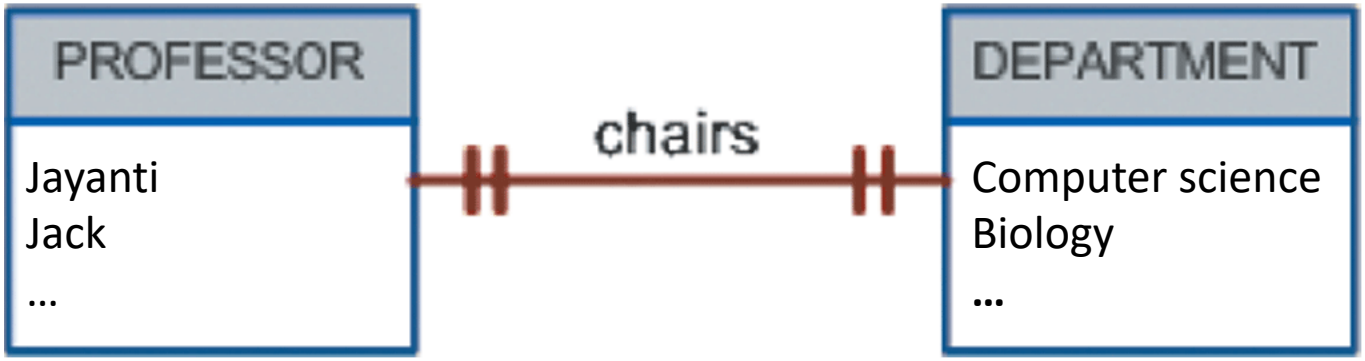
One-to-one (1:1)

One professor chairs one department

One department is chaired by one professor

Sometimes you cannot avoid them

One-to-one (1:1)

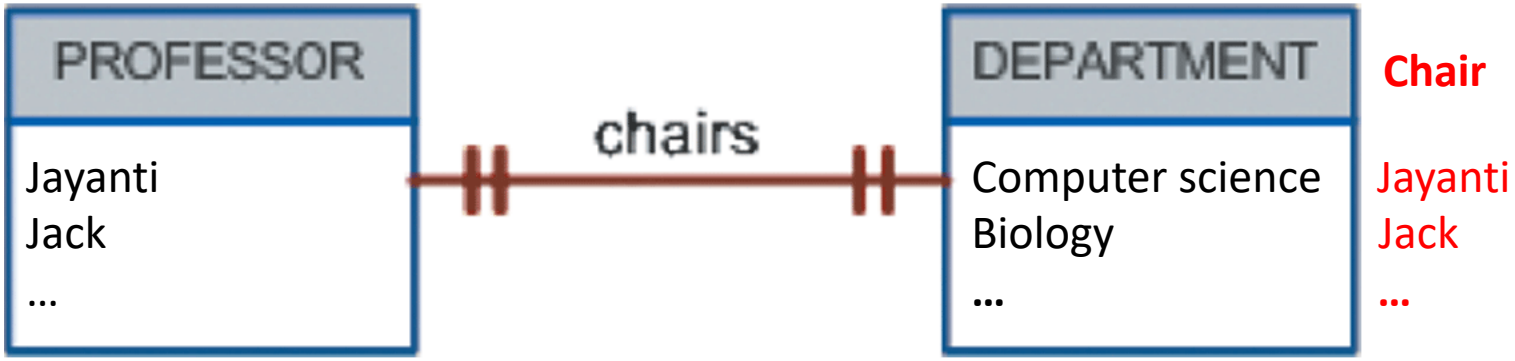


One entity can only be related to only one other entity in another table and vice versa

- **Often you would just combine the attributes of both tables into one table (look for two tables with the same PK)**
- **Sometimes you can't do that**

Implement using a column in one table and with a unique constraint

One-to-one (1:1)



To implement here:

- **Add a column in Department for the Chair**
- **Make Chair column unique (no duplicates allowed)**
- **Fill column with PK of Professor that chairs a department (e.g., Jayanti for CS)**
- **One department now has one chair (due to one attribute)**
- **One professor can only chair one department (due to unique on Chair)**

We will look at another variant next class

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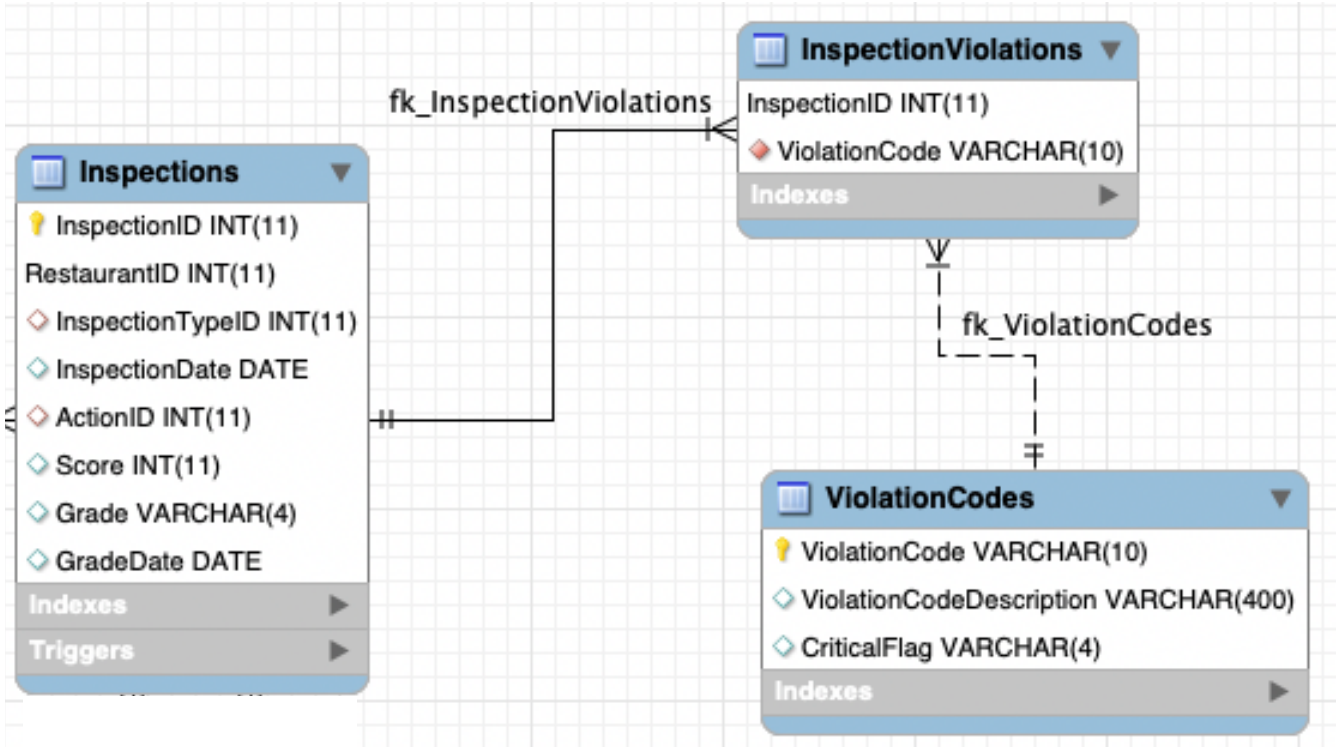
We have no direct way to model many-to-many relationships

Many-to-many (M:N)

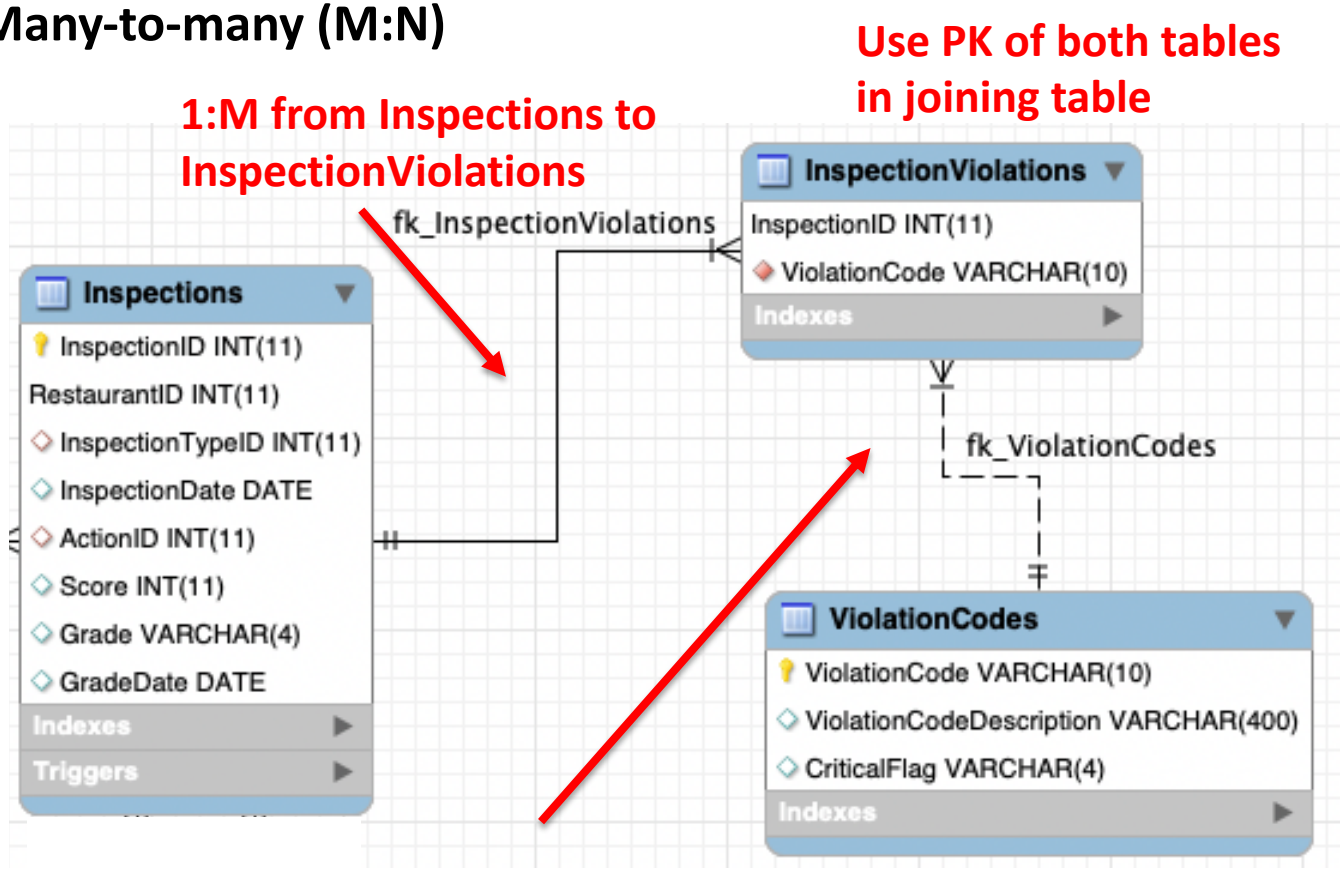


Problem:

- **One inspection can have many violation codes**
- **One violation code may occur in many inspections**
- **Many-to-many relationship**
- **We have no direct way to model M:N relationships**

Implement M:N with a joining table, create two 1:M relationships

Many-to-many (M:N)



NOTE: added InspectionID to Inspections table for convenience

1:M from ViolationCodes to InspectionViolations

Problem:

- One inspection can have many violation codes
- One violation code may occur in many inspections
- Many-to-many relationship
- We have no direct way to model M:N relationships

Solution:

- Use a joining (bridging) table (InspectionViolations here)
- Create two 1:M relationships

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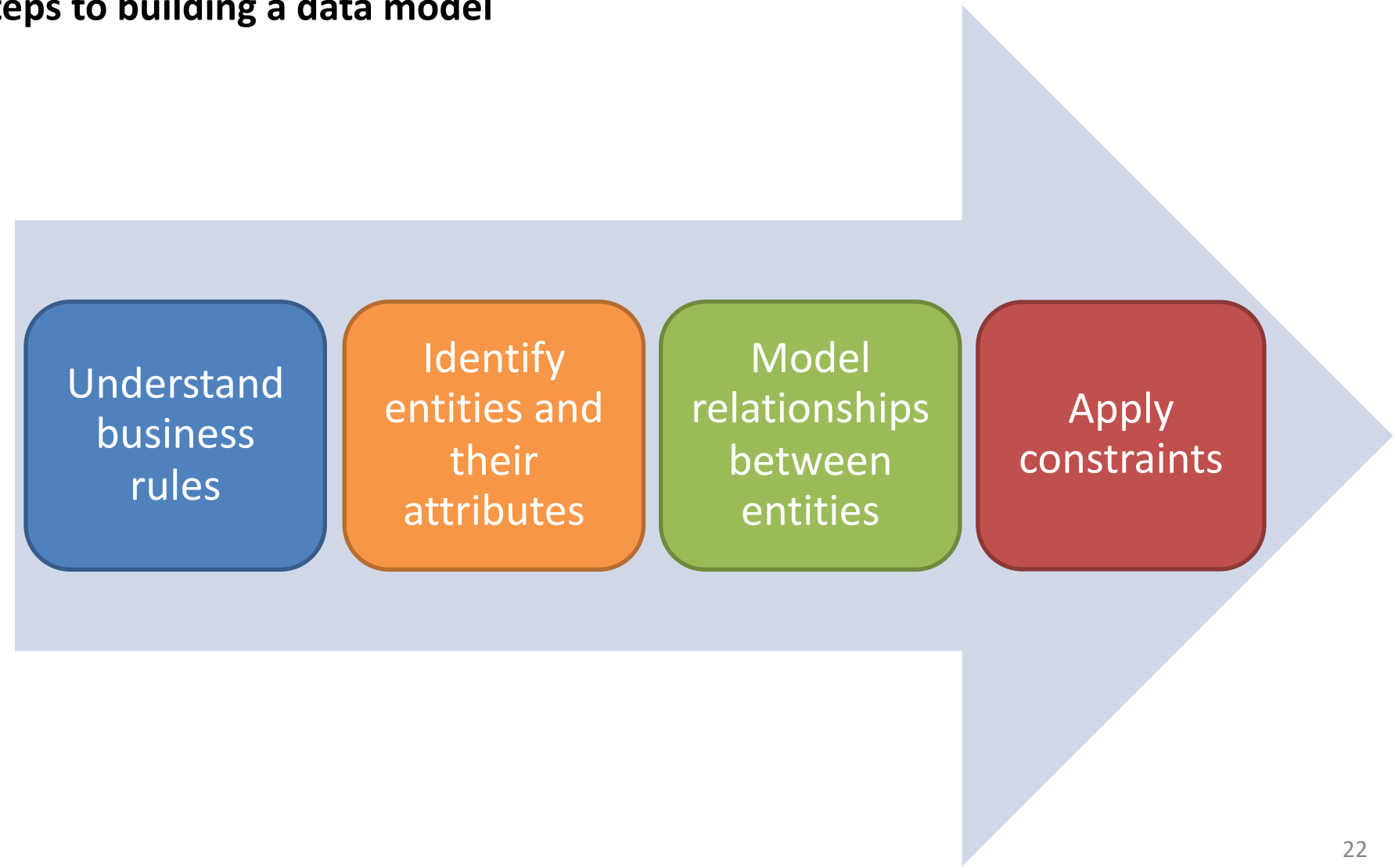
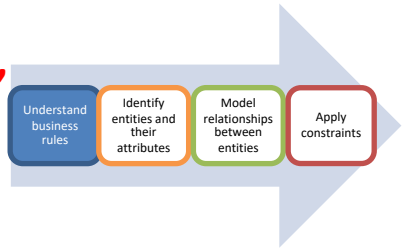
Data models are a (relatively) simple expression of the real world; build in steps

Steps to building a data model



First understand business rules so you know how the system should behave

Understand business rules **Output of this work is sometimes called a "specification of functional requirements"**



What are business rules?

- "Business rules" really means organization's rules
- "Brief, precise, and unambiguous *written* description of a policy procedure, or principle within a specific organization"
- Important to get this right!

Example:

- The college has many departments
- Each department belongs to one college (e.g., Arts & Sciences, Tuck, Thayer, Geisel, …)

How to I learn about the business rules?

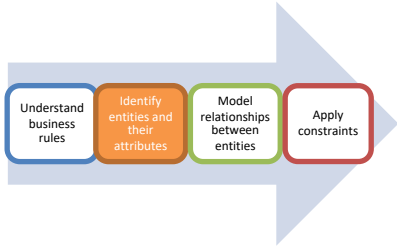
- Review written procedures – tells you how things *should* be done
- Talk to people to find out how it *does* work:
  - C-level – Have view of large portions of the organization, think they understand details, but frequently do not
  - Mid-level managers – know their part of the organization, but may not have big picture of how pieces work together
  - Users – might tell you how it really works

- Written business rules often help organization understand itself better
- Can lead to "business process engineering" to make organizational changes
- Consultants make lots of money doing this!

Next identify the entities (the nouns) involved and create them in the database

Identify entities and their attributes

Once entities and attributes established, create tables with DDL commands



Entities

- Person, place, thing, or event (noun)
- Normally become tables in the database
- Examples: Employee, Customer, Product
- Entities instances (rows) should be "distinguishable" from other entities based on keys

Attributes

- Characteristic of an entity
- Example: First name, Last Name, SSN

Some advice about naming

- I like to prefix attribute names with the entity name
- Example:, CustomerName CustomerAddress
- I think of this like a namespace
- Helps prevent confusion later (e.g., does Name mean customer name or product name?)

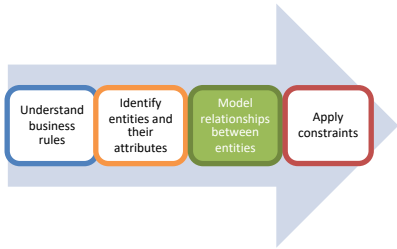
```
#create new database
CREATE SCHEMA 'new_schema';

#create student entity as table with
attributes and their types
CREATE TABLE STUDENT (
        STU_NUM int,
        STU_LNAME varchar(15),
        STU_FNAME varchar(15),
        STU_INIT varchar(1),
        STU_DOB datetime,
        STU_GPA numeric(4,2)
);
```

I prefer to spell out STUDENT (not STU) and LastName (not LName)

Then model relationships between entities (the verbs) using 1:M, M:N, or 1:1

Three types of relationships between entities



One to many (1:M or 1..*)

- Associations among two or more entities where one entity is associated with two or more other entities
- Example
  - A painter can paint many paintings
  - Each painting is only painted by one painter
- Ask question in both directions:
  - How many instances of B (paintings) are related to one instance of A (painter)?
  - And how many instances of A (painter) are related to one instance of B (painting)
- Other examples?

Many to many (M:N or M:M or *..*)

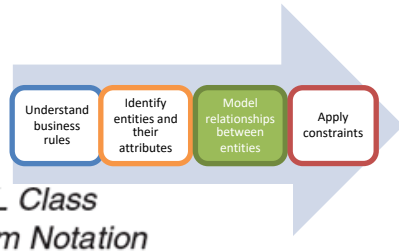
- Employee may learn many skills
- More than one employee can learn a skill
- We have to model these relationships using a joining table

One to one (1:1 or 1..1)

- A store is managed by one employee
- An employee can only manage one store

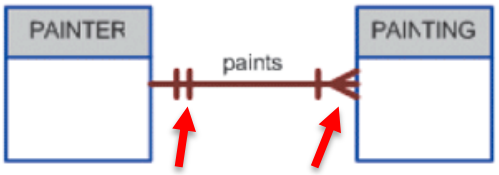
Draw relationships on an Entity Relationship Diagram using 1 of 3 formats

Three types of Entity Relationship Diagrams (ERD)

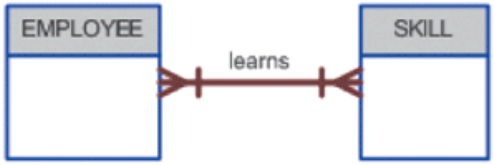


Chen Notation | ***Crow's Foot Notation*** | *UML Class Diagram Notation*

A One-to-Many (1:M) Relationship: a PAINTER can paint many PAINTINGs; each PAINTING is painted by one PAINTER.



A Many-to-Many (M:N) Relationship: an EMPLOYEE can learn many SKILLs; each SKILL can be learned by many EMPLOYEEs.

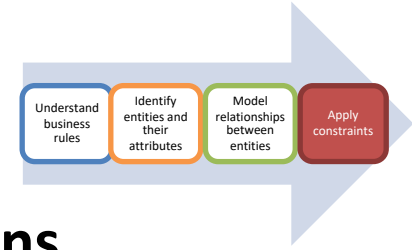


A One-to-One (1:1) Relationship: an EMPLOYEE manages one STORE; each STORE is managed by one EMPLOYEE.

Source: Coronel and Morris

Finally apply any attribute constraints

Apply constraints



Attributes are sometimes limited to particular domains

- GPA must be between 0 and 4.0
- Employee's salary must be between $10K and $1M

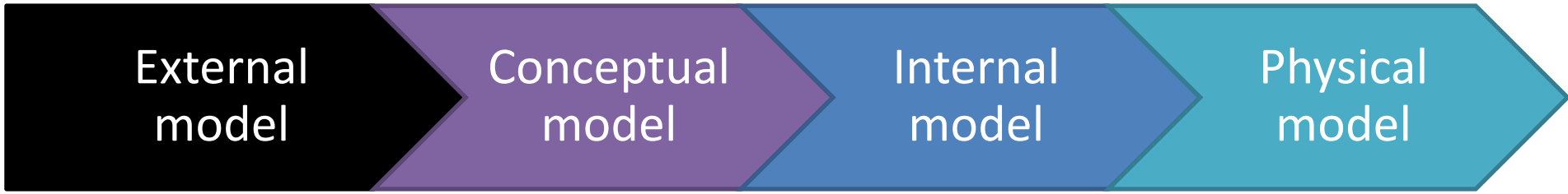
Add CHECK constraint when defining table (e.g., GPA double CHECK (GPA >=0 and GPA <=4)

Once everything is set up, Data Manipulation Language (DML) allows us alter the database contents

- Perform CRUD (create, read, update, delete)
- SQL is both DML and DDL

Apply these steps in a phased approach

Design phases



- Models a subset of the total problem
- Work with end users to get this right
- Hardware and software independent

External schema

- Combine external models into global view of the entire database
- Work with managers to get this right
- Hardware and software independent

Conceptual schema

- Database's view
- Considers the specific DBMS used (e.g., Oracle vs MySQL vs Mongo)
- Hardware independent
- **Software dependent**

Internal schema

- How the database will be deployed on actual hardware
- **Hardware dependent**
- **Software dependent**

Physical schema

Adapted from Coronel and Morris

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DEMO: Reverse engineer an existing database

Reverse engineer nyc_inspections on sunapee

- From MySQL Workbench choose Database->Reverse engineer
- Make connection to database (sunapee here, so make sure you are VPN'ed into Dartmouth!)
- Select nyc_inspections
- Re-arrange tables

DEMO: Forward engineer a new schema based on a new ERD

Forward engineer a new schema

1. Create new ERD
   - From MySQL Workbench choose File->New model
   - Change schema
   - Add diagram
     - Add tables
     - Add relationships (start from many side, then connect one side!)

2. Create schema
   - Database->Forward engineer to create new schema based on ERD

Practice

Forward engineer a database according to the following rules to track painters, paintings, and galleries for a famous art museum:

- A painting is painted by a specific artist and that painting is exhibited in a specific gallery
- A gallery can exhibit many paintings, but each painting can be exhibited in only one gallery
- Similarly, a painting is painted by a single painter, but each painter can paint many paintings